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FIRST QUARTERLY PROGRESS REPORT

PREPARED UNDER
U. S. ARMY SIGNAL CORPS CONTRACT
DA-36-039 AMC-03278(E)

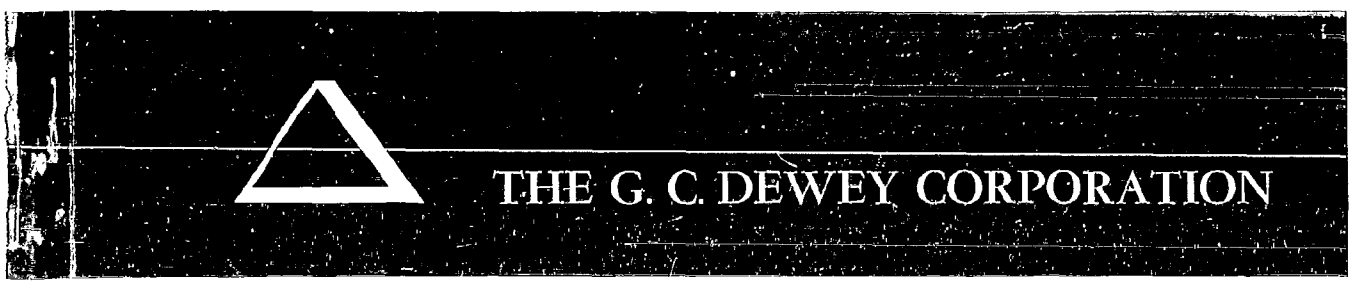
UNDER THE TECHNICAL SUPERVISION
OF THE ATOMICS BRANCH OF
THE APPLIED PHYSICS DIVISION
U. S. ARMY SIGNAL RESEARCH AND
DEVELOPMENT LABORATORIES
AT FORT MONMOUTH

by

M. N. HIRSH
P. N. EISNER

R-173-1

30 SEPTEMBER 1963



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AN EXPERIMENTAL INVESTIGATION OF THE EFFECTS OF RADIATION ON THE PROPOGATION OF ELECTROMAGNETIC SIGNALS IN AIR

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30 September 1963

THE G. C. DEWEY CORPORATION
202 East 44th Street
New York 17, New York

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I. INTRODUCTION

This is the First Quarterly Report of an experimental program continuing the work begun under contract No. DA-36-039-SC-87318, "An Experimental Investigation of the Effects of Radiation on the Propagation of Electromagnetic Signals in Air". The purpose of the study is the measurement of reaction rates for various charge production and loss mechanisms in electron-irradiated air and atmospheric gases. Of particular interest in this program is a study of the effects of radiation-generated chemical species on the charged particle reactions. The reader is referred to the final report of the earlier program (The G. C. Dewey Corporation Report R-146-8, 30 June 1963) for details of the experimental techniques used and results obtained prior to the period covered in this report.

This Quarterly Report includes work performed in the period 1 July to 30 September 1963. It describes progress on the construction of an rf mass spectrometer for use in ion and neutral species identification and measurement, as described in Final Report R-148-8, as well as work on the preparation of the vacuum system for bakeout at elevated temperatures. The period has been devoted exclusively to construction and equipment modification, in order to make the results of the next series of experiments more meaningful. The report closes with a description of work anticipated for the next period.

II. VACUUM SYSTEM BAKEOUT MODIFICATIONS

We have previously described the effects of wall-occluded impurities on the observed ionization densities in our experiments. To minimize these effects, it is necessary to bake the cavity at high temperatures while evacuating it prior to filling with experimental gas. It is believed that the most serious wall contaminant in our cavity is water released from the zeolite (Linde Molecular Sieve 13-X) in the diffusion pump baffle during its activation. To remove water effectively from steel surfaces, a wall temperature of at least 200°C is required. Higher temperatures are useful for removing organic contaminants and gases trapped some distance below the surface of the steel. Because our system includes several Pyrex components, we set an upper design limit of 400°C for safety.

To permit the cavity to withstand the large thermal stresses encountered at 400°C, two mechanical changes were made. First, the back of the cavity was braced with 2" square stainless steel beams in the pattern shown in Figure 1. The beams were made by welding 2" angle into a box pattern as shown in the insert to the figure. The beams were heliarc welded to the cavity with continuous beads along the two lines of contact.

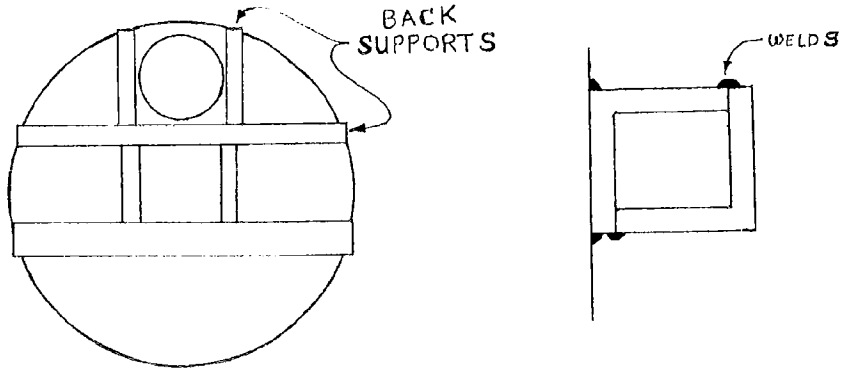
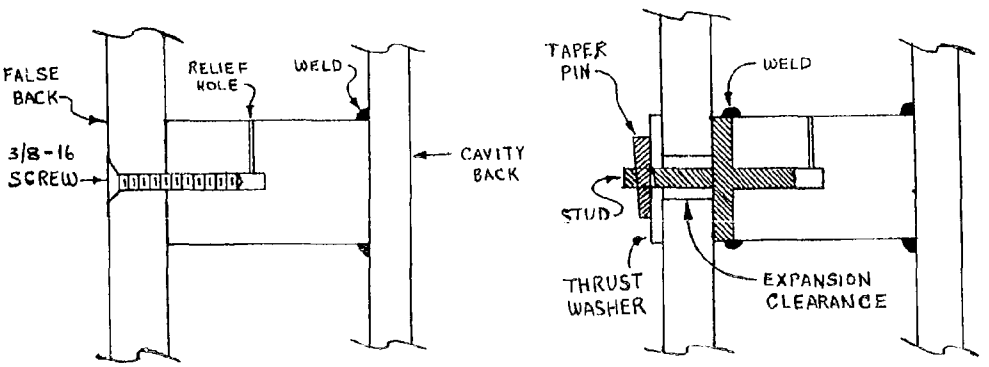


FIGURE 1

The other cavity modification was the remounting of the false back plate used as a mode separator. The previous method of holding the plate was be screwing it into tapped studs welded onto the back of the cavity, as shown in Figure 2a.



(a) (b)

FIGURE 2

The flat-head screws held the plate rigidly to the cavity back, prohibiting all relative motion along a diameter. Since the back plate is heated primarily by conduction through the studs, whereas the cavity back is in close contact with the oven, temperature differences between the two pieces, hence large thermal stresses, must be expected while the cavity is being brought up to temperature or cooling down after a bakeout. Thus, the retaining screws were in danger of being sheared from the studs. In addition, although all screw threads were vacuum relieved, it is not good vacuum practice to use screws, which present large areas almost impossible to clean. Inserts were therefore welded into the studs to pass through oversize holes in the backplate, which is then held in place with washers and taper pins, as in Figure 2b. The oversize holes now permit enough diametral slippage to avoid thermal stresses, and the screw threads are incidentally removed from the vacuum system.

Several vacuum components had to be changed in order to permit bakeout. The original 6" valve between the diffusion pump stack and the cavity was not bakeable as it used a phosphor-bronze bellows shaft seal, held in place by a low melting point solder. A 6" Granville-Phillips valve, constructed entirely of heliarc-welded 304 stainless steel, and bakeable to 450°C, was substituted. The rf coupler was rebuilt, and its ceramic feedthrough was hydrogen brazed to a crush-metal flange with a silver-copper eutectic, permitting it to be exposed to high temperatures.

The gas handling system described in the final report[1] was rebuilt of 304 stainless steel tubing all of which is either hydrogen brazed or heliarc welded. Stainless steel regulators have been obtained to control the gas flow out of the steel storage cylinders, replacing the brass regulators formerly used. This greatly reduces contamination of the experimental gas samples. The entire gas handling system can be baked with heating tapes up to these regulators, although the regulators themselves cannot be baked above 225°F. The Granville-Phillips capacitance manometer has been reinstalled as the gas pressure measuring device.

An oven was constructed for the cavity in the following way. Twelve heating tapes of 500 watts each were wrapped around the cylindrical sides of the cavity. Parallel to the back of the cavity and about 4" away from it is a circular transite slab, 55" in diameter and $\frac{1}{2}$" thick, on which coiled nichrome heaters were mounted facing the cavity. An insulating blanket, made of 0.003" aluminum foil sandwiched between two asbestos blankets was then wrapped around the cavity sides and was clamped tightly to the edge of the transite slab and to the flange connecting the cavity to the beam tube, forming a 2" air gap surrounding the cavity.

During bakeout, the following equilibrium temperatures were recorded:

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1. Final Technical Report R-146-8, 30 June 1963, The G. C. Dewey Corp.

Cavity back	$400^{o}C$
Cylindrical portion	$200^{o}C$
Beam Tube-Cavity Flange	$140^{o}C$

The above temperatures were obtained with cooling water circulating through the beam tube-cavity flange. It suggest that either the power input to the sides of the cavity or the insulation of the blanket were inadequate to maintain a uniform temperature throughout the cavity volume. This will be remedied in the future.

In order to test the new Granville-Phillips 6" valve, the cavity was shut off from the pumps, and the zeolite trap heated for about four hours, after which the trap was permitted to cool. An ultimate pressure of $4x10^{-8}$ Torr was recorded in the stack. The cavity was then opened to the pumps, and baked simultaneously with the zeolite trap for about 36 hours. The system was then allowed to cool. As the temperature of the system dropped, the pressure was recorded. It dropped continuously to $4x10^{-7}$ Torr in the complete system with everything still quite warm. Then it began to rise again. It was discovered that this rise was due to corrosion of the aluminum foil window by the cooling water, despite the fact that the latter was deionized to reduce electrolytic etching. The foil leaked cooling water into both the beam tube and the cavity, so that the test had to be terminated.

In the future, Viton O-rings will replace the Neoprene gaskets currently used in the large flange and bakeout to $250^{o}C$ will be performed without cooling of the flange, to avoid a repetition of the foil etching. There is good reason to believe, however, that after a proper bakeout of the cavity to $250^{o}C$, pressures in the 10^{-8} Torr range can be achieved. For the present, it has been decided to continue experiments with the cavity unbaked, until the Viton gaskets are obtained and installed.

III. MASS SPECTROMETER

A. Introduction

The preliminary design of the mass spectrometer had been developed under the previous contract.[1] During this quarterly period the detailed design of the spectrometer was completed, the spectrometer was built, and testing was begun.

Full details of the design and operation of the spectrometer will be given in a subsequent publication of this research group. In the present report, an outline will be presented of the progress of the instrument during this quarterly period with details given for only the more important aspects of the spectrometer.

B. Construction Details

The mass filter itself is a modification of the rf quadrupole called a monopole, as originally described by Von Zahn[2]. Actually the monopole is one quadrant of the quadrupole and makes use of the symmetry of the electric field configuration in the latter. Thus, the monopole consists of a rod electrode and an electrode in the shape of a "vee" (Figure 3). In principle, the quadrupole field derives from cylindrical electrodes of hyperbolic cross section, but pole pieces circular cross section can approximate the field quite well. Dayton, Shoemaker and Mozely[3] have shown that a ratio of circular electrode radius to field radius of 1.16 gives the best approximation to the hyperbolic field.

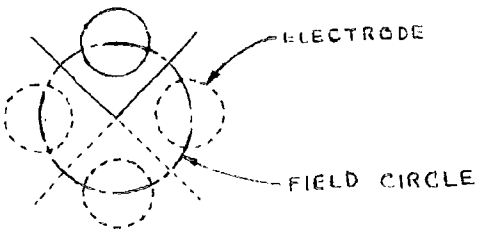


FIGURE 3

1. G. C. Dewey Corp., loc. cit.
2. U. von Zahn; Rev. Sci. Instr. 34, 1 (1963)
3. I. E. Dayton, F. C. Shoemaker, R. F. Mozley; Rev.Sci.Instr. 25, 485 (1954).

Figure 4 shows the mechanical assembly of the electrodes. The structure consists of three major parts, all of 304 stainless steel. The rod is made from a length of precision ground stock, 1 3/8" diameter, screwed onto the rod mounting plate. The rod mounting plate is aligned relative to the vee bar by retractable pins and is secured to the vee bar with insulated screws which pass through boron nitride spacers. The rod mounting plate is cut out as shown to provide additional pumping speed for the gap between the rod and vee electrodes.

The monopole is contained in a cylindrical housing which serves several functions. First, it is a vacuum chamber to permit differential pumping between the relatively high pressure gas input and the low pressure required in the analyzer and detector. Second, it shields the lens from the high rf voltage applied to the rod. Finally, it aligns and supports the monopole relative to the rest of the apparatus. Figure 5 is a cross-sectional view of the forward vacuum chamber containing the focussing lens and the cylindrical monopole housing. The monopole is supported in part on its vee electrode by a steel pin attached to the front of the housing, which is maintained at the accelerating potential, that is, the dc voltage applied to the vee electrode. The front of the housing, which also contains a triangular entrance aperture to the monopole, is insulated electrically from the rest of the housing by a ceramic ring seal, so that the back of the housing can remain at ground potential despite the accelerating voltage on the front. The remaining supports for the monopole consist of two projections mounted at the rear of the housing, on which the vee electrode rests, as shown in Figure 6. The supports are insulated from the rest of the housing by ceramic feedthroughs, so that they also provide electrical contact with the vee electrode for the application of power supply voltages. The rod electrode voltage is fed through a ceramic-to-metal busing on the top of the monopole.

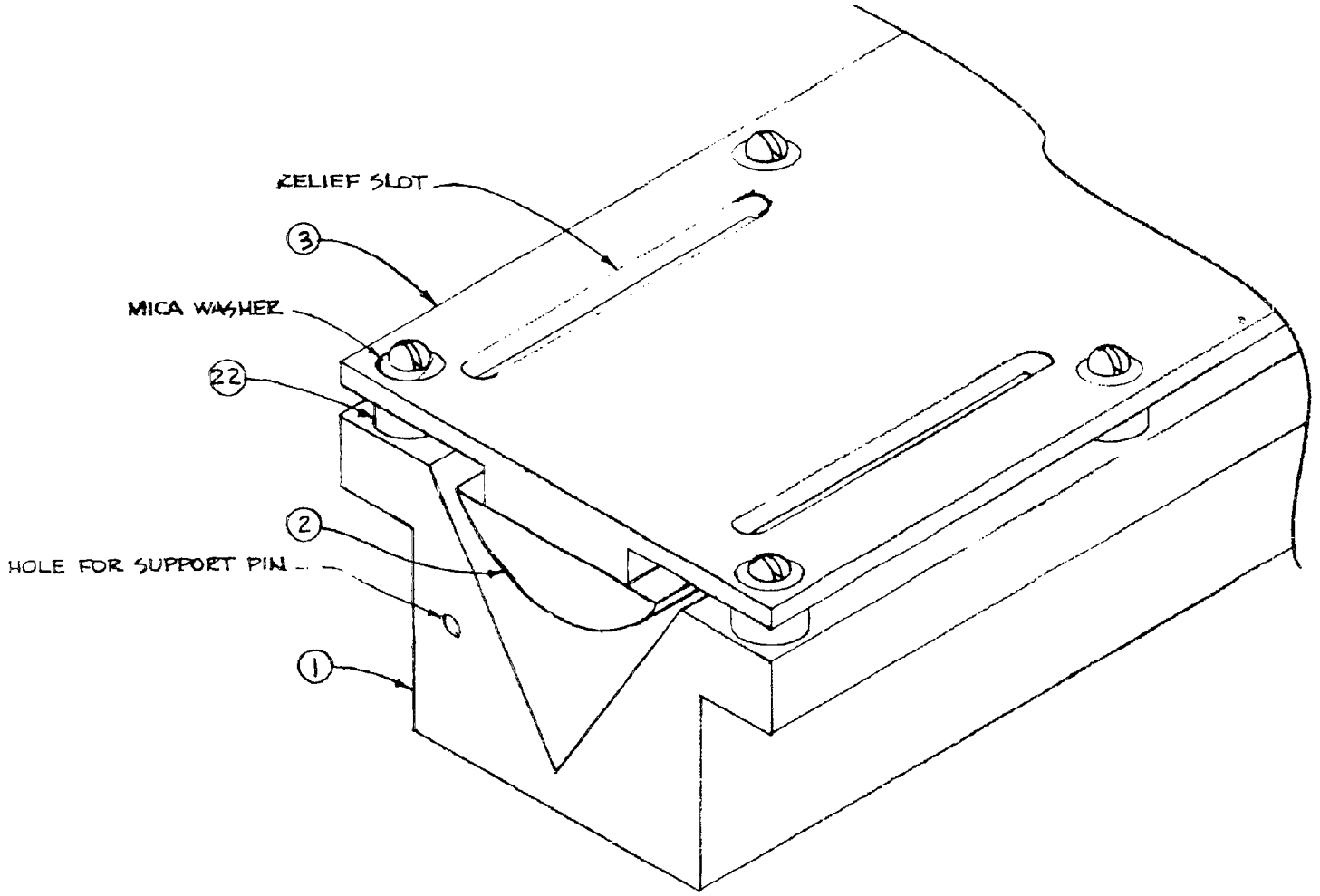


FIGURE 4 - MONOPOLE FRONT END DETAIL

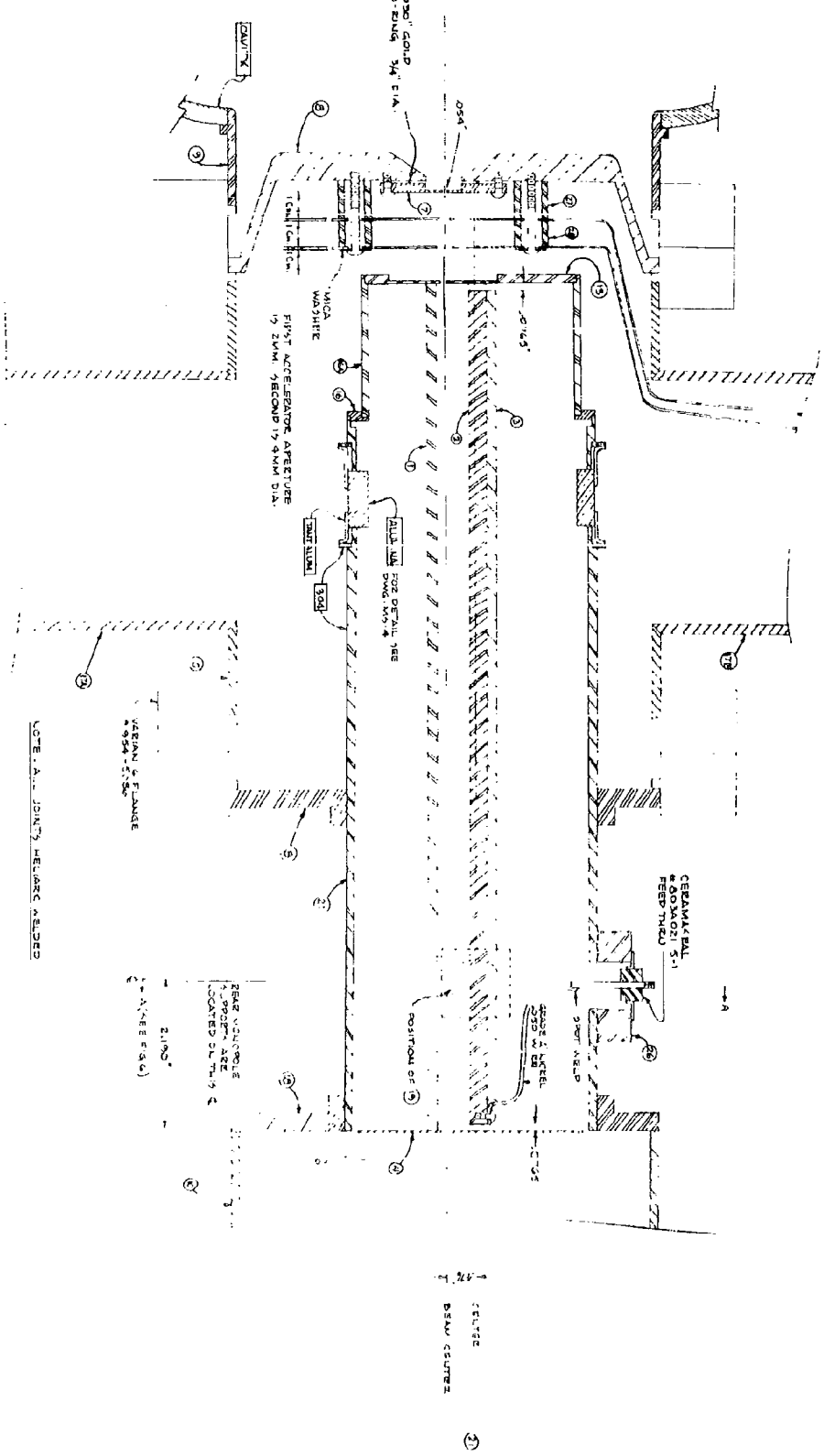
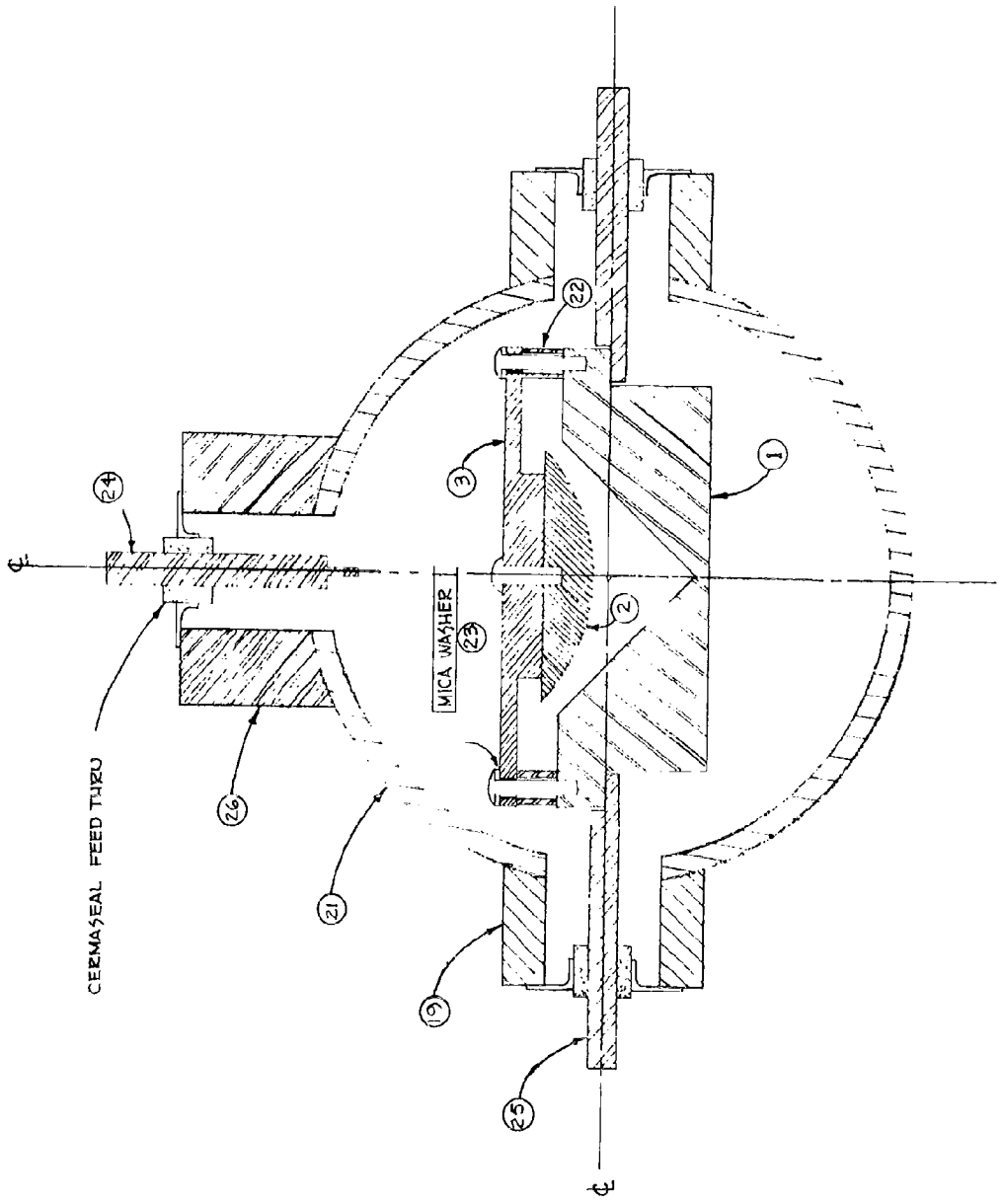


FIGURE 5 FOWARD VACUUM CHAMBER



SECTION A-A

FIGURE 6—MEDIAN CHAMBER & MONOPOLE

The monopole housing is shielded at the rear by a circular plate which contains a triangular aperture similar to the entrance aperture. The plate is perforated (except in the region near the electrodes) to increase the pumping speed of the monopole housing and is screwed onto the vee electrode. Its diameter is smaller than the housing inner diameter to prevent a short circuit between the vee electrode and the housing.

In order to use the spectrometer in experiments on gas at pressures as high as 10 Torr, the monopole and the ion detector are isolated from the cavity containing the gas by a separately pumped chamber, the "forward chamber" shown in Figure 5, into which the monopole housing protrudes. The ion lens and the demountable aperture to the cavity are screwed onto the front face of this chamber. The aperture is drilled into a circular plate which seals to the "front plate" with a gold "O" ring. Thus, the aperture is at ground potential. An electrostatic lens consisting of two coaxial diaphragms is mounted between the front aperture and the monopole aperture so that the apertures are equally spaced.

The rear chamber of the spectrometer houses the detector and a nude ionization vacuum gauge. This chamber is evacuated by its own diffusion pump and is maintained at the lowest pressure in the system. The detector, a Dumont electron multiplier, is mounted on the flange at the rear of the chamber. Electrical feedthroughs in the flange make connection to the electrodes of the multiplier. During preliminary testing a Faraday cup is substituted for the multiplier.

C. Electronics

A block diagram of the electronics for the mass spectrometer appears in the Final Technical Report, R-146-8, 30 June 1963. During this quarter all of the electronics was designed and constructed with the exception of the signal amplifiers.

Figure 7 is a schematic of the rf oscillator which is a Hartley oscillator tunable from 730 kcps to 9.39 mcps. It works directly into the monopole which presents a capacitive load of less than 100 $\mu\mu$fd and produces a peak to peak rf voltage of 1000 volts over the entire tuning range. The rf oscillator is rigidly but demountably attached to the mass spectrometer by a brass coaxial coupler between the oscillator chassis and the rf feedthrough on the monopole housing. This arrangement minimizes the capacitance seen by the oscillator yet provides good shielding.

The rf oscillator, the high voltage keyer for the electron-multiplier (Figure 8), and the signal preamplifier are the only pieces of electronic equipment which are mounted on or near the mass spectrometer. All the rest are contained in a relay rack in the radiation shielded room adjacent to the experimental room.

D. Vacuum Testing

Immediately after the mass spectrometer was assembled its vacuum system was tested. A small brass cup was sealed (with a Gask-O-Seal) onto the front of the spectrometer as a substitute for the cavity. The cup was fitted with three insulated electrodes so that a dc discharge can be maintained in gases introduced through a valve attached to the cup.

Without baking, the mass spectrometer reached an ultimate pressure of 2×10^{-8} Torr. Using the brass cup to simulate the cavity pressure, air was admitted into the cup and cup pressure versus mass spectrometer pressure was determined. There are two vacuum gauges in the mass spectrometer. One is a nude gauge in the detector chamber; the other is a Hastings-Raydist thermocouple gauge in the front chamber. For cup pressures less than 500 microns, the front chamber pressure was less than 1 micron using a .050 inch diameter aperture between the front chamber and the cup. For cup pressures less than 250 microns, the detector chamber pressure was less than 3×10^{-6} Torr. This behavior agrees well with calculations.

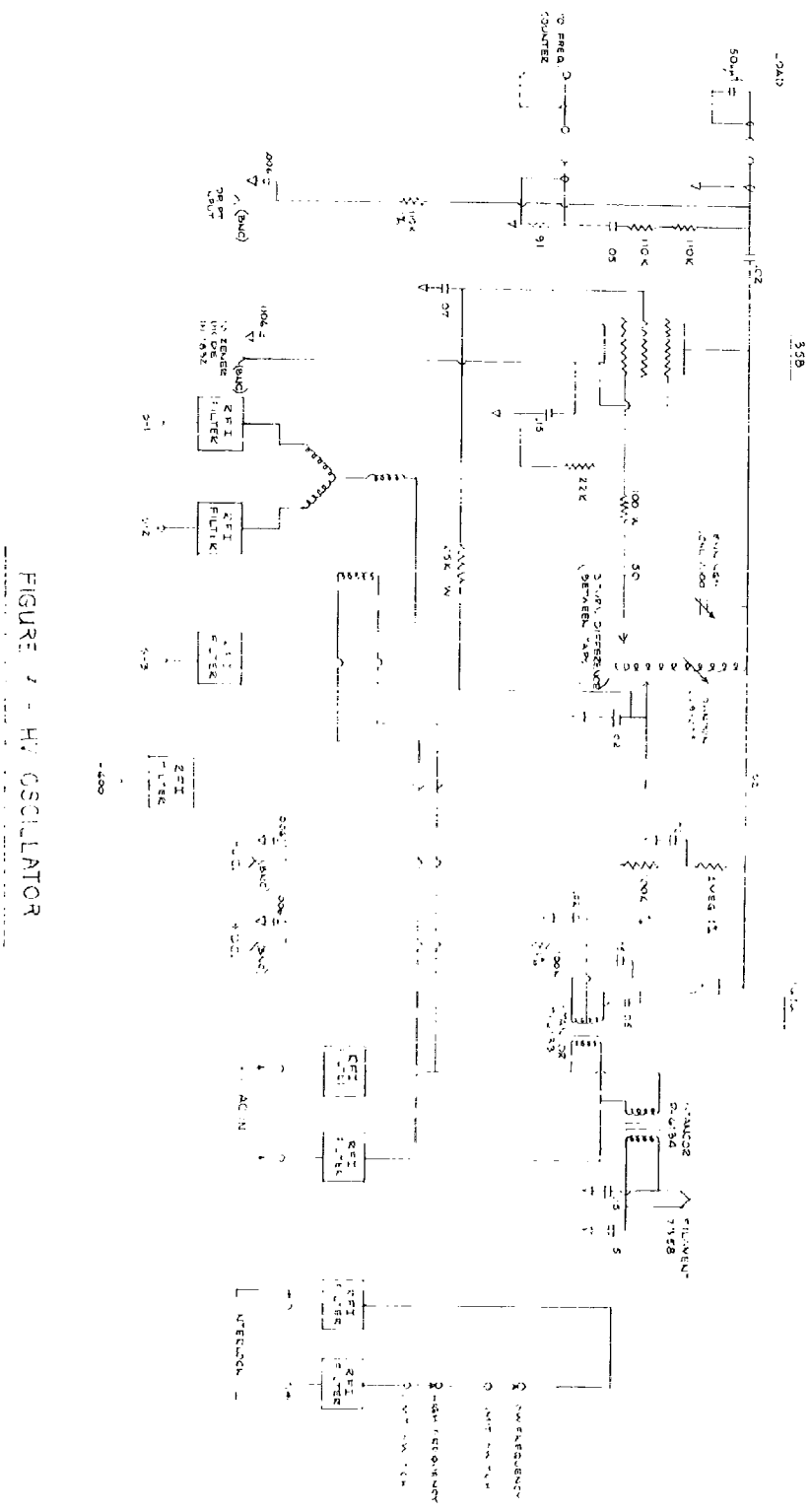


FIGURE 1 - HV OSCILLATOR

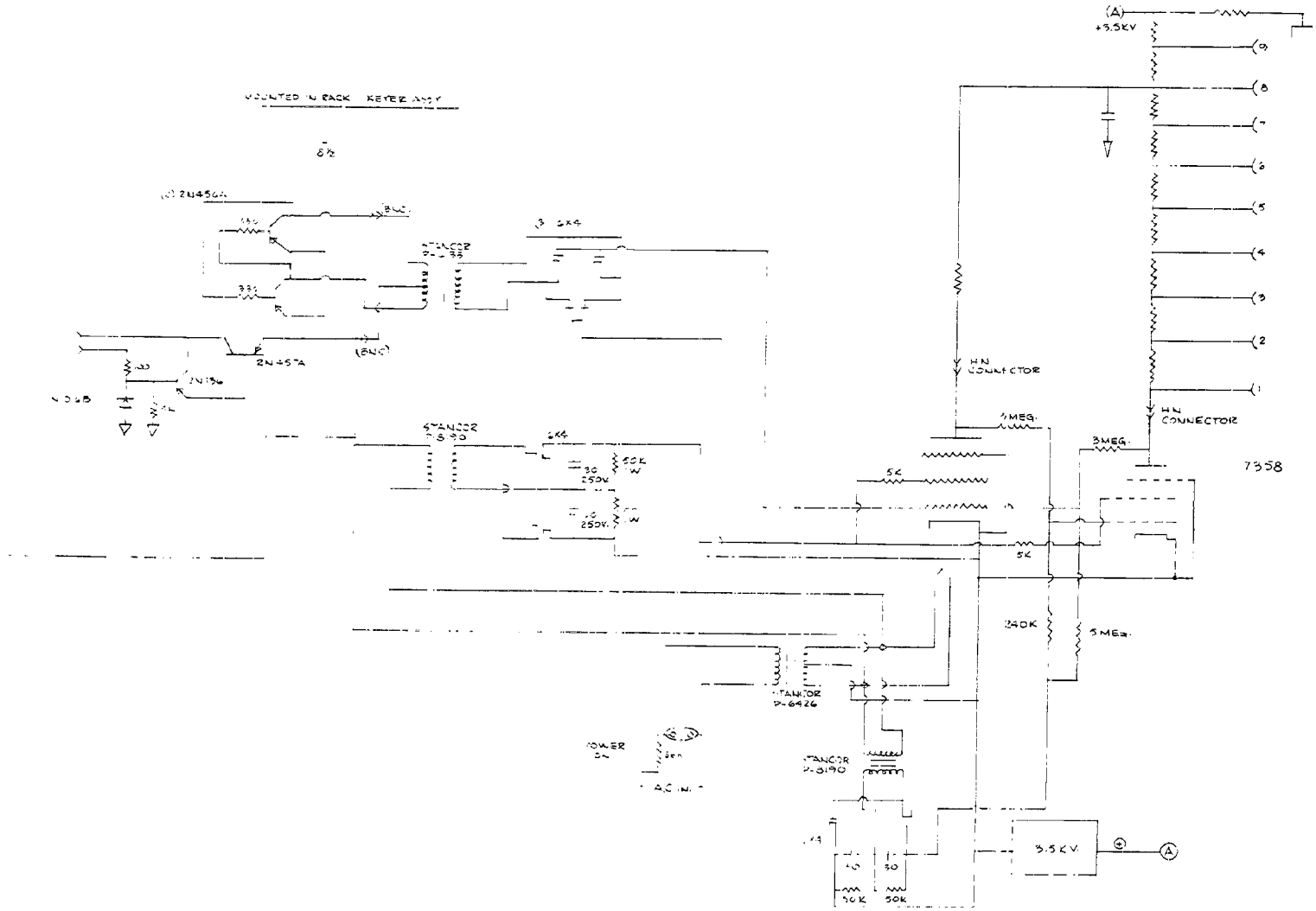


FIGURE 5 - KEYER

IV. WORK ANTICIPATED DURING THE NEXT REPORT PERIOD

The program will move forward on several fronts during the next report period. Most important of these will be the testing of the mass spectrometer with ions produced in a dc discharge in the brass cup. The object of these experiments will be to determine the calibration of the instrument and the behavior of the detecting system prior to attaching it to the cavity. These preliminary tests must be performed with the mass spectrometer separate from the cavity to avoid our having to shut down the entire cavity-beam tube system for possible modifications of the spectrometer. The mass analyzer must be made ready for use in the cavity experiments as rapidly as possible, so that we can evaluate the importance of impurities in the low pressure behavior, as well as follow the parent-gas ion populations during the experiments. The calculations relevant to the design of the optical system necessary for the proper illumination of the 0.5 meter optical spectrometer will be started during the next period. If time permits, the measurements of electron density begun during the earlier program will be continued, in an attempt to extend our present understanding of the deionization problem as far as is possible prior to the addition of mass and optical spectroscopy to the diagnostic program.

Second Quarterly Progress Report

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